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Operation

CASTLE

PACIFIC PROVING GROUNDS

May 1954

INTERIM RAD PROCEDURES

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HEADQUARTERS FIELD COMMAND ARMED FORCES SPECIAL WEAPONS PROJECT

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OPERATION CASTLE

Project 6.1

TEST OF INTERIM IBDA PROCEDURES

~~REPORT TO THE TEST DIRECTOR~~

Mar - May 54,

(10) by

[redacted] Rockly Triantafellu, [redacted]

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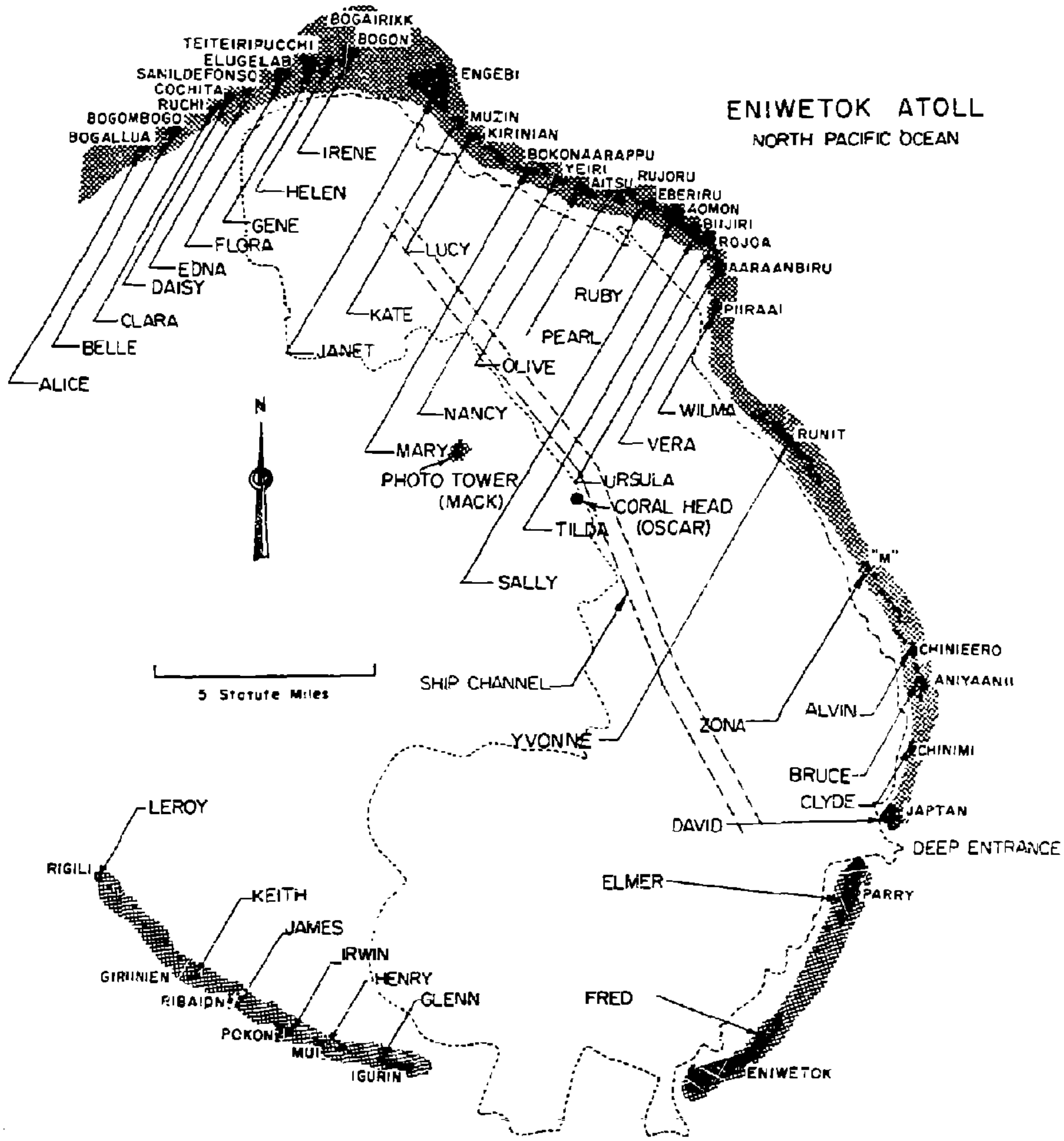

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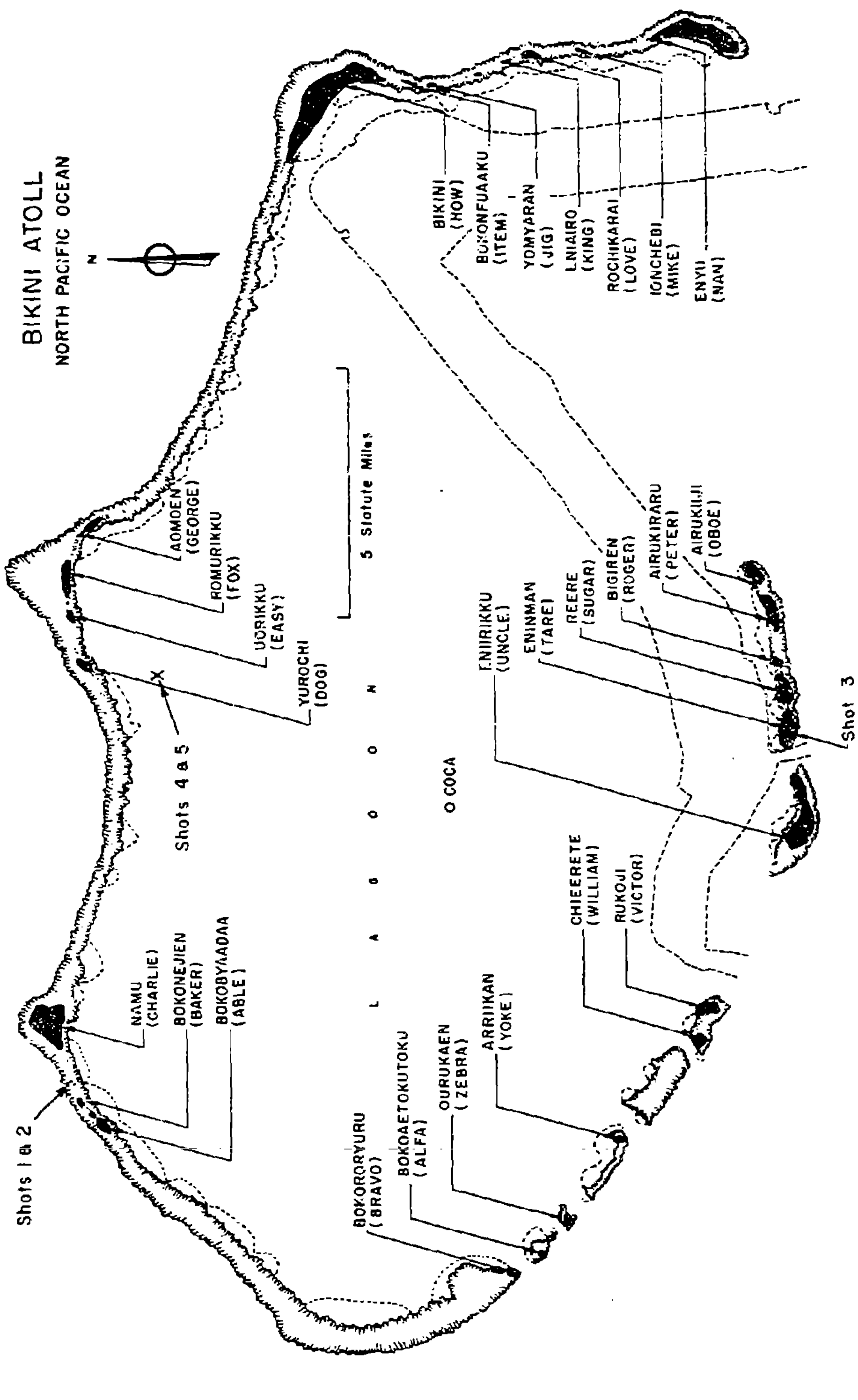

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GENERAL SHOT INFORMATION

	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6
DATE	1 March	27 March	7 April	26 April	5 May	14 May
CODE NAME (Unclassified)	Bravo	Romeo	Koon .	Union	Yankee	Nectar
TIME*	06:40	06:25	06:15	06:05	06:05	06:15
LOCATION	Bikini, West of Charlie (Namu) on Reef	Bikini, Shot 1 Crater	Bikini, Tare (Eninman)	Bikini, on Barge at Intersection of Arcs with Radii of 6900' from Dog (Yurochi) and 3 Statute Miles from Fox (Aomoen).		Eniwetok, IVY Mike Crater, Flora (Elugelab)
TYPE	Land	Barge	Land	Barge	Barge	Barge
HOLMES & NARVER COORDINATES	N 170,617.17 E 76,163.98	N 170,635.05 E 75,950.46	N 100,154.50 E 109,799.00	N 161,698.83 E 116,800.27	N 161,424.43 E 116,688,15	N 147,750.00 E 67,790.00

* APPROXIMATE

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ABSTRACT

The objective of Project 6.1 (CASTLE) was to determine whether the equipment-operating procedures used in obtaining radar scope photos for IBDA (Indirect Bomb Damage Assessment) of previous A-bomb tests were valid for thermonuclear weapons. The procedures for obtaining the radar photos involved positioning of bombers at a safe distance from ground zero at operational altitudes, with radar scanning ground zero during, and immediately after, the weapon burst. The photography obtained on each shot was generally good. The conclusions are that a high yield weapon burst can be readily detected by the bomber's radar, and that present equipment-operating techniques are adequate. These conclusions must be qualified by the point that since none of the test weapons were air drops, no data were obtained on techniques of obtaining radar photos of the burst by a strike or drop aircraft. It is recommended that in any future air drop of a high yield device, the drop aircraft obtain radar photos of the burst.

FOREWORD

This is one of the reports presenting the results of the 34 projects participating in the Military Effects Tests Program of Operation CASTLE, which included six test detonations. For readers interested in other pertinent test information, reference is made to WT-934, Summary Report of the Commander, Task Unit 13, Programs 1-9, Military Effects Program. This summary report includes the following information of possible general interest.

a. An over-all description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the six shots.
b. Discussion of all project results.
c. A summary of each project, including objectives and results.
d. A complete listing of all reports covering the Military Effects Tests Program.

ACKNOWLEDGEMENTS

Project 6.1 of Operation CASTLE has provided important operational knowledge on techniques of obtaining data with strike or supporting aircraft for rapid assessment of target damage. That this knowledge was obtained is due almost entirely to the 97th Bombardment Wing ADVON's efficient execution of its assignment in CASTLE.

The 97th Bombardment Wing Commander, Colonel (now Brigadier General) Keith K. Compton, his Deputy, Colonel Charles F. McKenna III, and the staff and crews of the 97th Bombardment Wing ADVON, accorded Project 6.1 complete support. Every attention was given to the project although it was an overload to the ADVON's commitments to maintain combat readiness and to meet specific overseas rotational training requirements.

The crews made 23 separate flights from Guam to the Pacific Proving Grounds and back (approximately 2400 nautical miles each) for a total distance of some 55,000 nautical miles. In addition to operations connected with Project 6.1, the ADVON flew a special hurry-up radar reconnaissance mission over the Pacific Proving Ground for Task Group 7.4 and special crater photography for Task Group 7.1. In the case of the 7.4 mission, the unit received its instructions while enroute from the Zone of Interior to Guam, briefed its crews, executed the mission, and dispatched the film to the Zone of Interior, all within a matter of hours. The film was urgently needed to decide whether a last minute civilian contract was necessary for construction of radar reflectors to aid in positioning aircraft. The reflectors were not needed and considerable savings in money were made.

The cooperation and services rendered by the 97th Bombardment Wing ADVON in CASTLE are in themselves noteworthy, but special acknowledgment is made of their hard work and efficient operation in making Project 6.1 a success.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

It has been demonstrated that atomic explosions could be photographed under clear weather conditions with oblique aerial cameras in the bomber. Military necessity, however, dictates that emphasis be placed on the all-weather capability of radar as the primary means of recording such explosions for Indirect Bomb Damage Assessment (IBDA). It was the primary objective of Project 6.1 to add to existing knowledge on radar recording of high yield weapon bursts (see Phase 1 of Section 1.1.1), and in so doing, train a nucleus of Strategic Air Command crews in the recording techniques. Secondary objectives were to exercise capability of SAC to accomplish Phases II and III, IBDA. (Section 1.1.1)

1.1.1 Definitions

Certain definitions pertaining to IBDA as used in Strategic Air Command may assist in understanding the objectives of Project 6.1. The definitions are:

Indirect bomb damage assessment is the estimation of damage to targets from nuclear weapons, based on actual ground zero, height of burst, and weapon yield as determined from strike data. IBDA differs from BDA (Bomb Damage Assessment) in that physical damage is not determined directly from post-strike photography of the damaged area.

IBDA is composed of three phases:

Phase I, IBDA, is the gathering of strike data. These data are obtained by strike or support aircraft and include aerial photography, radar scope photography, bhangmeter photos, camera and flight logs, and aircrew estimates and observations.

Phase II, IBDA, is the initial interpretation of the strike data. This phase includes the determination of ground zero, height of burst and weapon yield.

Phase III, IBDA, is the assessment of damage. It is the estimation of the extent and probability of damage to a specific installation or facility within a target complex, and is based on Phase II findings, available target materials, and weapons capability.

1.2 MILITARY SIGNIFICANCE

The effectiveness of the strategic air offensive as it progresses is of vital concern to all levels of command. High priority targets must be destroyed in the shortest possible time. An effective IBDA capability, utilizing strike data, is the most expeditious means of determining that this objective has been accomplished and/or providing the information for decision to reschedule strikes if necessary.

1.3 BACKGROUND AND THEORY

1.3.1 General

Previous tests at the Nevada Test Site and Pacific Proving Ground proved that the burst of atomic and thermonuclear weapons could be detected and photographed with airborne navigation-bombing radars and camera system.

Project 6.1 was designed to extend existing knowledge over previous operations by acquiring data on procedures for obtaining and utilizing radar scope photos of high yield weapons for purposes of IBDA. The plan included investigation of effect of aircraft distance from ground zero on the radar display of the weapon burst. This was accomplished within limitations of the radar tracking range by positioning one aircraft at the closest safe distance from ground zero, one at maximum radar tracking range (approximately 28 miles), and one at an intermediate distance from ground zero (see Appendix C). It can be stated here that at these ranges no differences in the radar ability to detect and record the weapon burst at different ranges were observed.

The reasons that airborne radar systems detect atomic and thermonuclear explosions are not known by the author. The fact that the explosions manifest themselves on the radar display in a distinct shape, composed of a positive and a negative return, may have a complex scientific explanation, particularly the cause of the negative "return". Several theories have been advanced in the past as to the cause of the positive return, such as the creation of some material by the explosion having a dialectric property capable of reflecting radar energy, or the compression of properties already suspended in the atmosphere to a density capable of reflecting radar energy. However, the explanation generally agreed upon by personnel experienced in operating radar, and an explanation they can understand, is that the positive return is caused by the disturbance or upheaval of the surface beneath or surrounding the explosion.

The cause of the negative return is less easily accounted for by operational personnel. The popular belief is that the fire ball, stem and cloud absorbs or completely attentuates radar energy. Applying the principles of radar, if the negative return were caused by space being evacuated of anything capable of returning radar energy, then it would seem the radar would look through and see beyond the burst. Apparently this does not occur, hence the belief that radar energy is absorbed. A further discussion of this supposition is contained in Annexes G and K of SAC Operations Order 6-54 (see Appendixes A and B).

It is believed that the clarity of the shock wave on radar displays caused by high yield weapons will be readily observed over land surfaces; perhaps even more pronounced because of the R.F. energy reflecting characteristics of the materials being affected by the shock wave.

1.3.2 Factors Affecting Accuracy in Plotting Ground Zero

Before discussing the factors contributing to or limiting accuracy in plotting radar scope photos, a figure of 700 to 1100 feet plotting error is presented as a basis for discussion. This figure is based on results of plotting several thousand scope photos by photo interpreters of SAC. The figure was derived by plotting the position of radar cross-hairs relative to aiming points on routine radar bomb runs. The plotted positions were compared to simulated bomb impact points as scored by MSQ-2 radar bomb scoring equipment. There is, of course, some small error in the scoring equipment (MSQ-2), however, in the absence of any other available data, the impact point computed by the equipment is accepted for practical scoring purposes as absolute; and the difference between this point and the photo interpreter plotted cross-hair position is considered the photo interpreter plotting error. The figures (700 to 1100 feet) were generally substantiated by the ground zeros plotted on the CASTLE shots wherein the position of the geometric center of the circular or horseshoe shaped return was plotted against the exact ground zero as known from the physical location of the shot site. The factors that limit accuracy in plotting ground zero from radar scope photos are not presented in order of their magnitude, as they affect plotting, because the direction of the error inherent in the factors is not always known. However, for a large sample the root mean square sum of the errors could be found.

For example: assuming plotting is done by superimposition of the radar pattern on a graphic or chart of the same scale, and error in matching features is 400 feet due to inherent radar resolution error; the error in matching due to the graphic being in error is 400 feet; and the error due to interpretation by the plotter is 200 feet; the root mean square of the sum of these errors is 600 feet:

$$\sqrt{400^2 + 400^2 + 200^2} = 600 \text{ feet}$$

The separate major component errors in plotting are discussed in the paragraphs that follow.

The range settings of radar bombing systems in the US Air Force (AN/APQ-24 and K-Series) are continuously variable when the system is in the bombing mode. However, an average of 20 nautical miles will be used for the purpose of this discussion. This means that the distance being displayed on the scope from the origin of the sweep (edge of scope) to the opposite side of the scope is 20 miles. The size of the scope is approximately 4.5 inches. The scale of the display, if photographed and reproduced to a one to one size, is approximately 1:324,000 or 1 inch on the photo equals 25,355 feet on the surface mapped and

photographed by the radar. Breaking this down further, 1 millimeter (one twenty-fifth of an inch) equals 1,000 feet. This begins to make the size of points on proportional dividers a consideration in plotting. However, by projection methods the photo can be enlarged; not infinitely but to the size of available graphics with which the photo is to be matched. (See Appendix B for description of this technique) The scale of the graphic may vary, but considering the physical size for handling purposes, the scale of the graphic necessary to portray sufficient detail for plotting and the size of the area necessary to equal the area mapped by radar, the graphic which best meets these requirements is the USAF Target Complex Chart, Series 100 (Scale 1:100,000). Using this chart and enlarging the one to one radar photo approximately three times, by projection for superimposition the one twenty-fifth of an inch described earlier now equals about 350 feet as a unit of measurement for plotting.

Error of the plotting chart

If the plotting chart was a perfect compilation and the radar scope photo had no distortion, plotting by matching of features would be relatively simple and accurate. However, in constructing charts some errors are made in positioning features with respect to each other, both in azimuth and in distance. This positional error varies, depending on the skill of the chart maker, the accuracy of the source material and the geodetic data used in the construction of the chart. In general, the most accurate chart is defined as one having position accuracy within 200 feet; the average chart, within 400 feet.

Inherent radar resolution errors

The AN/APS-23 radar (basic to the AN/APQ-24 and K-Series bombing systems) has inherent resolution errors which cause distortion of features mapped by the radar. In the main, excluding input and output errors of internal electronic components and external components such as the compass, the inherent resolution errors can be considered the functions of beam width, pulse length, spot size of the cathode ray tube, and imperfect ground range sweep. Again using a 20 mile range setting to compute the size of these errors as they affect the accuracy of the features displayed on the scope, it is observed that:

A beam width of 1.5 degrees (AN/APS-23) causes a point target to be enlarged 3,000 feet in a direction perpendicular to the radar sweep. (1,500 feet on both sides of the center line of the beam at 20 nautical miles.)

The pulse length of .375 micro seconds in duration (20 mile range setting) causes a point target to be extended 185 feet along the radial axis of the sweep, away from the origin of the sweep. However, the leading edge of the target (nearest to the sweep origin) is not affected by pulse length.

The physical size of the electron beam in the cathode ray gun, plus the surrounding glow of phosphor on the face of the gun when the beam strikes it, causes the physical size of the illuminated spot to be equal to 1,800 feet, relative to a 20 mile range setting. This

limitation causes a point target to be larger on all sides. The actual spot size may vary with tube phosphors, receiver gain, and electron beam efficiency. The relative size of the spot with respect to features being displayed, varies with the range setting of the radar and the diameter of the cathode ray tube.

The AN/APS-23 radar employs a hyperbolic sweep plus a value equal to altitude in order to convert slant range measurements to a ground range presentation. The accuracy with which this conversion is accomplished is not known, but undoubtedly varies with efficiency of the radar set. It is known from discussion of this problem with the design engineers that in the original design of the AN/APS-23 there was no requirement for a precise conversion. It was believed at the time that an approximate ground range presentation was adequate for visual map matching by the radar operator. The error, whatever its magnitude, is greatest near the origin of the sweep, and where plotting of features is attempted in this area, distortion in ground range seriously limits plotting accuracy. The addition of the AWA-2 (Position Mark Generator) to the AN/APS-23 radar could provide a means of compensating for imperfect ground range measurements by providing an accurate visual slant range scale to correct the ground range measurements. Installation of the AWA-2 (Position Mark Generator) on SAC bombing systems is underway.

There is one other feature of existing radar systems and recording cameras which causes distortion in radar scope photos, and this is the effect of the aircraft movement during the camera recording of the radar sweep. Using a normal picture rate of the radar system in bombing mode (sector scan) of approximately one stop-frame time exposure per second (exposure frequency depends on angular width of sector being used), an aircraft flying at 500 knots ground speed advances 850 feet between the beginning and the end of the scan. This means that a target scanned at the start of the scan may be in its true position on the photo, whereas a target scanned near the termination of the scan will be inaccurately positioned on the photo with respect to the first target, both in azimuth and distance.

The preceding discussion has attempted rather briefly to show the influence of various factors as they affect accuracy in plotting positions on radar scope photos. Considering these factors, it may be concluded that achieving plotting accuracies within the range of 700 to 1100 feet is a reasonable accomplishment for photo interpreters of combat units.

1.3.3 Estimation of Weapon Yield

The findings from CASTLE Project 6.1, concerning measurement of weapon yield using the time-distance formula with data recorded on radar scope photos, is contained in Chapter 3 (Results). However, for background, and in order to put this aspect of Project 6.1 in perspective, it is essential that the preliminary report (Test of IBDA Equipment, conducted in Operation TEAPOT, ITR-1141) be considered. The preliminary conclusion of that report (Section 3.2) was: "The yield-measuring device, Recording Set, Light and Time, AN/ASH-4 (XA-1), appears suitable for measuring yields of stockpile weapons with sufficient

accuracy for tactical situations." For reasons to be discussed below it is believed that the ASH-4 renders investigation of techniques for weapon yield measurement using radar scope photos, now only of academic and historical interest. However, at the time of the CASTLE test the capability of the ASH-4 had not yet been determined, and therefore a considerable effort was made to determine if weapon yield could be reliably computed from radar scope photo data.

If the theory expressed in AFOAT 385.2, Capabilities of Atomic Weapons, Revised Edition, 1 October 1952, Section II, paragraph 4b, is indicative of shock wave velocity and behavior for weapons with MT yields, the recording and timing of shock wave travel is most critical in the initial stages for determining weapon yield. For example, the last sentence in paragraph 4b of the manual referenced above states: "The difference between time of arrival at any given range beyond 1,000 yards for yields between 1 KT and 500 KT is negligible." While these figures do not apply to weapons of MT yields, the principle of early timing probably does apply. Recording and timing instrumentation available for CASTLE Project 6.1 could be considered grossly inadequate for such purposes if it had been intended to perform that function. However, it was not; in fact special instrumentation was purposefully not employed in order to test current capability of standard Air Force bombing systems to record weapon burst data for IBDA purposes. Measurement of weapon yield from such data as could be recorded was incidental to the project's purpose of determining whether high yield weapons burst could be consistently and reliably recorded for plotting ground zero and determining optimum radar operating procedures for obtaining the recordings.

Finally, all of the factors that limit accuracy in plotting ground zero (Section 1.3.2) also function to limit accuracy in measuring yield of weapons using radar scope photos. It is believed practical limitations in the form of equipment modifications prohibit instrumenting standard Air Force bombing systems to the extent necessary to record data for measuring weapon yield purely by time-distance measurements on radar scope photos.

The modifications believed necessary would include a rapid scan radar and a means of recording the time in fractions of seconds that the radar sweep coincided with the diametrically opposite sides of the circular shock wave pattern on each scan. No means can be visualized as to how identification of the sweep position and its relation to time could be accomplished. Perhaps a more gross timing method could be devised than the one just mentioned, which might prove adequate, however, the author is unable to evaluate this possibility.

1.3.4 Display of Shock Wave on Radar Indicator

The AN/APS-23 radar, at the option of the operator, may have a linear sweep (slant range presentation on the display) or a hyperbolic sweep (ground range presentation on the display). This control is effected by inserting or removing from the sweep circuit, a delay in the start of the sweep equal in time to the altitude of the aircraft. In normal operation a ground range display is desirable so altitude delay is used. This means that the sweep on the display is delayed by

an amount equal to the altitude of the aircraft, so that the first ground return below the aircraft is displayed at the origin of the sweep on the radar scope. It also means that the sweep must have a hyperbolic rate to compensate for the delay.

With the linear presentation the start of the sweep on the radar scope coincides exactly with the transmitted pulse of the radar. This means that the sweep travels outward on the scope at a constant rate from its origin, a distance equal to the altitude of the aircraft, before the transmitted pulse reaches the surface below the aircraft and returns. This condition is displayed on the scope as a circular "black" area around the origin of the sweep. The radius of this circular area represents the altitude of the aircraft. No targets can be seen in this "altitude hole" unless they are between the aircraft and the surface below the aircraft.

As indicated in the summary report of the Commander Task Unit 13 (ITR-934), some question existed as to whether the shock wave being displayed and recorded by the radar was on the surface or in free air. Radar scope photos of Shot 5, wherein altitude delay was removed from the radar system, show that the shock wave did not appear in the altitude hole, but rather took the distorted form that all ground returns take when an altitude hole is present on the radar display. (See example 3.5, photo number 5). This definitely indicates the shock front, as displayed on the radar scope, is on the surface and not in free air between the burst point and the aircraft. This fact was suspected prior to the CASTLE shots. (See Appendix B)

1.3.5 Radar Scope Photography

1.3.5.1 Radar Scope Photography on CASTLE Project 6.1

Obtaining acceptable photography (by existing standards) on this project was not difficult. Procedures differed little from routine procedures for operating the radar and camera systems. Aircraft were positioned at sufficient distance from ground zero as to preclude problems of the burst appearing close to the sweep origin on the radar display. Yield of weapons greatly exceeded the minimum yield (15-20KT) believed necessary to show on radar displays. Since no air release of weapons occurred, critical problems of break-away, leveling of aircraft, and the accompanying rapid succession of radar control adjustments (range setting, receiver gain, antennae tilt, etc) were not imposed. In this respect (no air release of weapon) the project could be considered deficient. It is hoped that future IBDA and high yield weapon tests will include air releases. However, returning to the quality of the radar photography obtained, it is believed that existing standards are too low and must be raised. The problems of using this photography for IBDA could be greatly reduced if certain improvements were made to the existing camera and associated systems. In view of these remarks and the previous discussion in Section 1.3.1, it is deemed appropriate here to describe certain programs aimed toward improving radar scope photography.

The discussion which follows covers those programs known to the author and some guidance for the future. In both cases it is to be observed that improvement is limited to modification of existing equipment. (Life span of the K-Series bombing system the B-47 and B-52)

1.3.5.2 Equipment Improvement Programs

Considering the integrated functions of the bombing system, camera and devices for recording weapon yield and height of burst for IBDA, any discussion of radar scope photography is necessarily likewise integrated with these equipments.

It can be accepted that a new radar with improved resolution would provide a better radar picture to be photographed. And after some ten years of radar scope camera experience, undoubtedly a better camera than the O-15 could be obtained. However, neither time nor funds can be expended on developing, testing, and installing new bombing systems and cameras in the existing SAC bomber fleet. In fact, the present bombing systems, having been in constant cycles of modification and improvement, are entirely adequate. On the other hand, while some improvements have been made to the O-15 system, there is still considerable room for improvement.

Prior to CASTLE, both WADC and SAC were engaged in programs having as their objective improvement of radar scope photography. The SAC program, in coordination with WADC, consisted of stating requirements based on experiments conducted by tactical units. The most important requirements were:

Improved phosphors and more efficient CRT's, primarily aimed at reducing spot size.

Increased size of CRT's to decrease effective spot size and to increase visual clarity of the display.

Illumination of tell-tale lights on the O-15 camera data plate to indicate bomb release, use of off-set system, use of memory point, and cross-hair displacement. All of these indicators serve the purpose of plotting cross-hair position as the predicted point of bomb impact in the event the weapon burst is not recorded and for back-up even if the burst is recorded.

An accurate scale recorded on radar scope photos for measuring distance. In conjunction with WADC, SAC tested the prototype Position Mark Generator, a device intended to display calibrated slant range marks on the radar display prior to bomb release.

Superimposition of a square reference grid on the borders of radar scope photos to facilitate reference to positions where the original negative is converted to prints by different operational units in widely dispersed areas. At present such grids are placed on photos in the processing laboratory, and each laboratory processing negatives for prints may employ different registration, thereby negating reference to common points by grid coordinates. It is not known whether future investigation of this feature has been considered by WADC. It should be.

The WADC program

WADC developed a better 5 inch CRT and it is believed that all SAC bombers now have them installed.

A larger CRT has been developed and is undergoing test.

The HICS program (High Information Content System) is probably the best over-all improvement yet proposed for improving radar photography. The system replaces the fixed focus lens of the O-15 camera with an adjustable focus lens including a peep sight through the lens, a reference image for focusing, and improved film magazine to maintain fixed distance of film-to-lens. The radar sweep circuit is modified to subdue the halation at sweep origin. A lighted azimuth ring is provided, visible to the camera lens but invisible to the operator. (Operator has an additional azimuth reference, illuminated at his option.)

The AWA-2, Position Mark Generator, was developed and tested and is currently being installed in SAC bombers.

A subsequent development, the APA-106, has not yet proven satisfactory because of certain automatic features which cannot be overridden manually when necessary, such as receiver gain.

In review, those modifications which have been incorporated in the O-15 camera system are: better CRT's, camera data plate light-bombing system tie-in, AWA-2, and better control mechanism. (Not described previously.) The HICS modification should be made to the O-15 as early as possible, and the best features of the AWA-2 and the APA-106 combined for a better position mark generating device.

1.3.5.3 Some Guidance for Follow-on Developments

It was learned in World War II and in Korea, that in the press of making the combat bomb run and breaking away from the target, picture taking for BDA purposes was frequently forgotten. Automaticity does not provide the complete answer to the problem. Primarily because of the variety of flight conditions (particularly aircraft flight attitude) that exist following bomb release. Some things can be assured of being done correctly by automatic controls while others must be done manually, based on human judgement. The present semi-automatic bombing systems are examples of this design principle.

Still confining discussion to improvement of existing systems for obtaining radar photography, those equipment adjustments believed best done automatically are:

Removal of altitude delay to provide altitude measurement at bomb release.

Re-inserting altitude delay (after recording its removal) in order to provide a ground range display for plotting purposes. This feature should be evaluated as to its merit considering scope distortion with altitude delay removed versus the inaccuracy of existing ground range displays.

Setting in optimum radar range setting.

Removal of off-set data at bomb release to insure radar display covers ground zero.

Switch from a sector scan to a 360 degree scan, or wide sector scan, if target features require broader scanning for plotting ground zero. (This should probably be an optional feature depending on target characteristics.)

Synchronization of all cameras and recording devices.

Those things which are best done manually based on human judgement of conditions existing at the time are: adjustment of receiver gain and associated display controls and antennae tilt setting.

CHAPTER 2

INSTRUMENTATION AND OPERATIONS

2.1 INSTRUMENTATION

Instrumentation consisted of B-50D aircraft equipped with standard APQ-24 radar and O-15 scope cameras. Positions of aircraft from ground zero and altitudes are shown in Table 2.1. Identification of individual aircraft in Tables 2.1 and 2.2 (Radar Data) may be done by reference to the altitude column in these tables. Aircraft positioning is covered in Annex E of SAC Operations Order 6-54 (See Appendix C). The Q-24 radar set is comprised of 2 major components: the AN/APS-23 radar and the AN/APA-44 Ground Position Computer. For detailed characteristics of the system see Table 2.3 or refer to T.O. AN 16-30 APQ-24-22. Radars scanned the displaced-from-center sector prior to and immediately after burst. Stop-frame camera exposures were obtained approximately every 1.25 seconds. After the shock wave on the water had expanded to a size equal to the 60 degree sector, radars were switched to a 360 degree scan with stop-frame camera exposures obtained every $2\frac{1}{2}$ seconds. Radars were tuned and adjusted for normal ground mapping. Type of film and camera f stops are shown in Table 2.1.

2.2 OPERATIONS

The operational planning aspect of Project 6.1 is fully covered in Strategic Air Command Operations Order 6-54 and Task Group 7.4 Operation Orders. On operational effectiveness, three aircraft were scheduled to obtain radar scope photographs on each of the six shots. One aircraft aborted on Shot 4 and one aircraft aborted on Shot 5. There were 16 successful sorties out of 18 scheduled (88.8 per cent effectiveness).

TABLE 2.1 - Aircraft Position and Photographic Data

Shot	Alt (ft)	Position from GZ (NM/heading in degrees)	Camera F Setting	Film (35 mm)	Contrast	Receiver Gain	Antennae Tilt (in deg)
1	32,000	15.5/222	4.0	Dup Sup 3	2	Medium	-5
1	31,000	23/225	4.0	Dup Sup 3	2	Medium	-10
1	29,940	27/225	4.0	Dup Sup 3	Unk	Medium	-5
2	32,000	17.5/230	4.0	Dup Sup 3	1	Med-Low	-2
2	31,000	24/226	4.0	Dup Sup 3	1	Medium	-8½
2	30,000	31/226	2.8	Dup Sup 3	0	Medium	-7
3	32,000	13/229	4.0	Dup Sup 3	2	Low	-7
3	31,000	20/224	4.0	Dup Sup 3	2	Medium	-5
3	30,000	30/225	4.0	Dup Sup 3	1	Med-High	-6
4	31,000	20/225	4.0	Dup Sup 3	0	Med-High	-5
4	30,000	27/210	4.0	Dup Sup 3	1	Medium	-7
5	32,000	15/225	2.8	Dup Sup 3	0	Med-Low	-15
5	30,000	29/228	2.8	Dup Sup 3	0	Medium	-5½
6	32,000	12.5/225	4.0	Dup Sup 3	Unk	Med-High	Varied
6	31,000	20/226	3.5	Dup Sup 3	2	Medium	-2½
6	30,000	27/225	4.0	Dup Sup 3	Unk	Medium	Varied

TABLE 2.2 - Aircraft Radar Data

	Preflight Check			Postflight Check		
Shot	Transmitt Pwr db	Recvr Sens db	Transmitt Freq mc	Transmitt Pwr db	Recvr Sens db	Transmitt Freq mc
1	43.7	101.5	9367	44.4	104.0	9363
1	43.8	101.0	9382	44.4	101.0	9381
1	44.0	100.0	9393	42.5	105.5	9396
2	42.4	101.9	9371	42.2	99.4	9370
2	42.6	101.9	9371	44.6	102.9	9380
2	43.4	100.4	9378	Too low to measure	100.5	9358
3	41.4	105.9	9363	42.4	100.4	9365
3	44.2	101.1	9382	44.2	96.4	9389
3	43.6	101.5	9376	44.0	102.4	9355
4	44.9	100.4	9355	40.0	103.4	9390
4	44.0	102.4	9355	44.6	104.2	9355
5	44.2	104.2	9355	44.1	103.5	9350
5	44.6	102.9	9380	45.4	102.9	9378
6	45.4	103.4	9381	45.4	103.5	9380
6	42.4	102.4	9365	42.1	102.2	9365
6	45.4	102.4	9378	45.2	102.1	9378

TABLE 2.3 - Radar and Camera Characteristics

AN/APQ-24 (AN/APS-23 Radar, AN/APA-44 Ground Position Computer and O-15 Camera)	
Frequency	9375 mc + or - 55 mc
Intermediate frequency	60 mc (for amplification)
Receiver sensitivity	- 80 db
Peak power output	55 KW (5 - 80 NM range)
Pulse recurrence frequency	800 pps (5 - 80 NM range) 200 pps (80 - 200 NM range)
Pulse length	3/8 ms (5 - 50 NM range) 1 ms (50 - 80 NM range) 5 ms (80 - 200 NM range)
Band width - IF amplifier	10 mc (for 5 ms PL 3 mc)
Band width - receiver	8 mc (for 3/8 and 1 ms PL)
Beam width	1.5 degrees (at ½ power point)
Antennae pattern	$\cos^2$ 55 deg vertical pattern
Antennae rotation 360 degrees	22 RPM clockwise
Antennae rotation 60 deg sector	One scan each 1.27 seconds (clockwise painting)
*Camera recording (O-15)	Stop frame exposure every scan

*As used on Project 6.1

CHAPTER 3

RESULTS

3.1 GENERAL

Phase I, IBDA (gathering strike data) was limited to radar photography of each shot. The necessary tactical type aerial cameras (K-17C with 6 in. cone), and bhangmeters were not available. Phase II, IBDA (initial interpretation of strike data) was accomplished by plotting GZ's from radar photography. Since shots occurred at ground level height of burst computations were not made. Although bhangmeters were not available in the 6.1 aircraft for measurement of weapon yield, an attempt was made to measure yield by timing travel of the radar-visible shock wave on the sea. A careful plotting of the radar scope photos indicated that computations of yield by this method are inaccurate (see 3.3 below).

3.2 PHASE I, IBDA

Acceptable radar scope photography was obtained in every case where attempted. The quality of the photography was generally excellent. Minor exceptions were noted where radar sets were malfunctioning such as spoking, etc., (see Fig. 3.3). Representative radar scope photo prints of each shot are contained in Figs. 3.1 through 3.6. Pertinent comments on these photos are as follows:

Reference Fig. 3.1, note a dash shaped positive return in the area of no return within horseshoe (photo Nos. 1, 2, and 3). No explanation is offered for this phenomena, although it is also observed on early pictures on Shots 2, 4, and 5 (see Figs. 3.2, 3.4, and 3.5). It is also observed that the land surfaces (part of atoll nearest the sweep origin) do not appear to slow up the shock wave (photo No. 5); the circular wave form still appears symmetrical on the outside of the atoll. The apparent distortion of the shock wave as indicated in photo No. 6 is believed to be the result of radar scope distortion. A three dimensional hard core effect is also observed at GZ on photo No. 5.

Reference Fig. 3.2, radar interference is observed on all photos. Rapid development of horseshoe during approximately 1 sec time interval is observed on photo Nos. 1 and 2.

Reference Fig. 3.3, the radar set is malfunctioning to a degree in that "spoking" and double azimuth markers are observed. There is an indication that the shock wave in free air is clearing the weather return from around GZ. Note photo Nos. 2 and 6, and 4 and 5; photo No.

2 indicates that whereas the surface shock wave has reached a point under the weather, that the shock wave in free air (not visible) apparently had not yet reached the weather.

Reference Fig. 3.4, the receiver gain of the radar is believed to be optimum on these photos, in that the gain setting provides a good "sea" return which causes the shadow from the cloud to stand out clearly. On photo No. 4 there is observed a stronger return on the far side of GZ than on the near side, although the leading edge of the shock wave appears stronger on the side nearest the aircraft. It is believed that antennae pattern (tilt setting) causes the former return, and that the "edge" effect of the shock wave approaching the aircraft position causes the latter type of return.

Reference Fig. 3.5, photo No. 4 shows uneven distribution of radar energy or the effect of so-called "ringing" in antennae pattern. This effect is produced by either aircraft flight attitude, antennae tilt setting, antennae shape or feed horn misalignment, or a combination of any of these, and undoubtedly accounts for many of the variations in "return" patterns. The effect of altitude delay being removed (photo No. 5), is covered in Section 1.3 of this report.

Reference Fig. 3.6, these photos indicate malfunctions of the radar in that focus is poor and "spoking" is present. The clarity of the clock image indicates the camera is not at fault. Some radar interference is noted. It is also observed on photo No. 6, taken approximately 1½ minutes after the burst, that the weather return inside the atoll (photo Nos. 5 and 6) was not noticeably affected by the shock wave.

A measurable growth of the right hand side of the shock wave on all the photos except photo No. 4 in Fig. 3.1 and photo No. 3 in Fig. 3.5 is observed. This phenomena is considered to be the result of the shock wave expanding during the time interval between the clockwise radar scanning of the left and right side of the wave.

3.3 PHASE II, IBDA

The land-water contrast of the Bikini and Eniwetok Atolls provided satisfactory radar interpretation conditions for plotting ground zeros. In a few instances radar interference and weather returns hampered but did not prevent accurate plotting of ground zeros (800 - 1,200 ft by several different photo interpreters). As mentioned previously, height of burst computations were not included in the interpretation. (See Appendix B for description of method which would have been used if test had included air bursts).

Weapon yields derived by time-distance measurements using data recorded on radar scope photos were so inconsistent with the known facts concerning the actual yield of the weapon that this technique was discounted as a reliable technique. For example, while subject to interpretation by different photo interpreters it was observed that the travel of the shock wave did not vary measurably with changing yields. The shock wave travels from a shot having a 14.5 MT yield and from a shot of 1.7 MT yield, for the same elapsed time, differed by a factor of approximately 1½, whereas the yields differed by a factor of

85. In fact, the shock wave from a 6.5 MT device outdistanced the wave from the 14.5 MT device for the same elapsed time. The uncertainty of time zero, slow scan rate and inherent radar resolution errors all contribute to the gross nature of these computations. As mentioned in Section 1.3.4 however, equipment has been developed (ASH-4) which, in the opinion of the author, obviates the need for further development of the techniques being discussed here. Laboratory techniques not available to operational commands may be able to refine the data obtained on Project 6.1 and increase the accuracy of yield determination using radar scope photos. All radar film and data obtained on Project 6.1 has been forwarded to WADC for that purpose, since that agency has primary responsibility for R & D on IBDA equipment.

3.4 PHASE III, IBDA

SAC exercised this phase of IBDA by superimposing data received from Phase II, IBDA, on a domestic target. The Atomic Energy Commission forecast of weapon yield and a simulated height of burst were used in producing a synthetic estimate of damage on the domestic target. An exercise was accomplished on each shot.

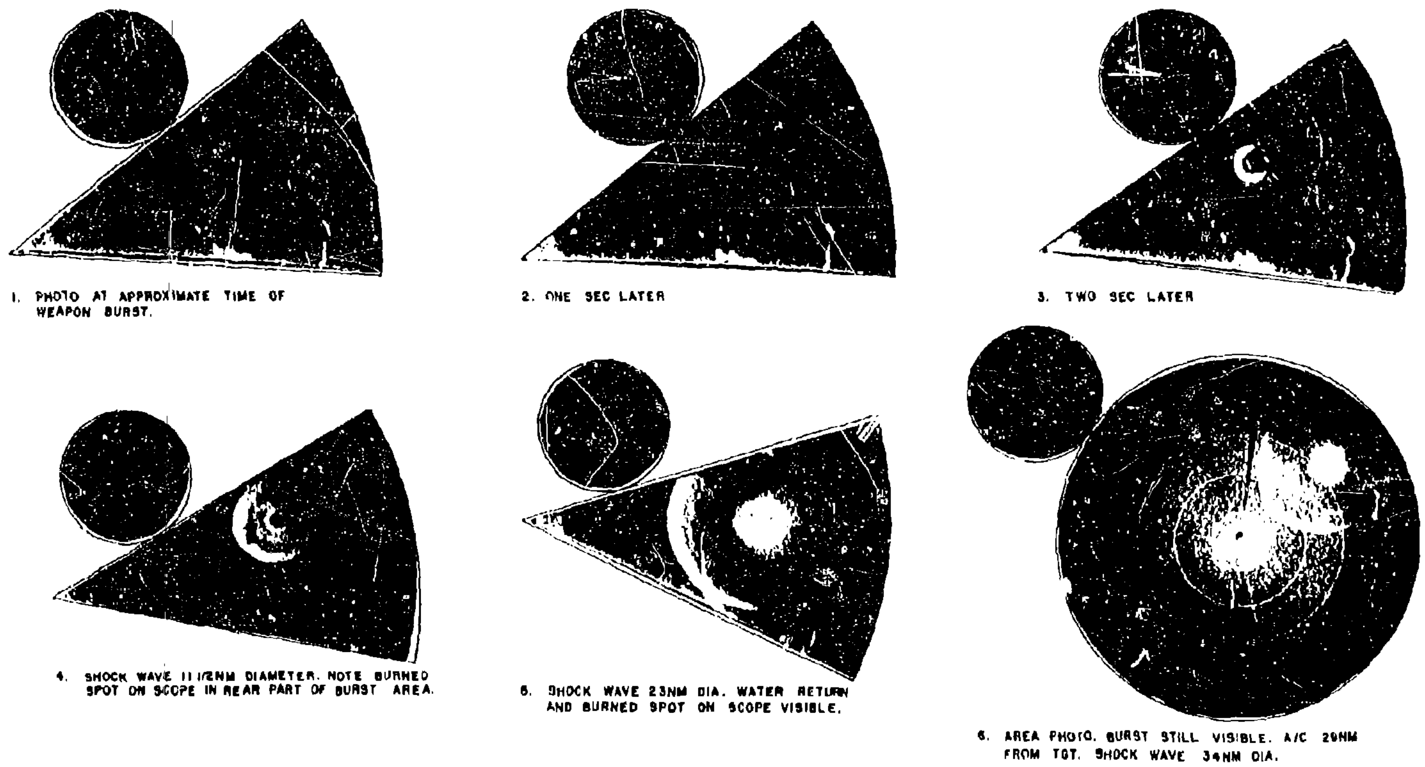
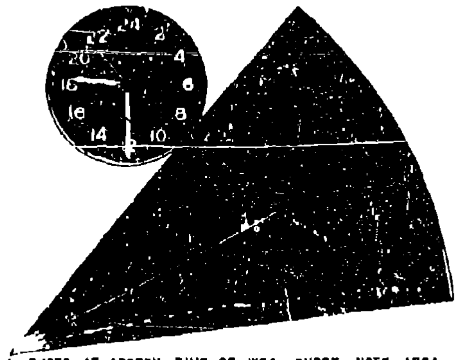
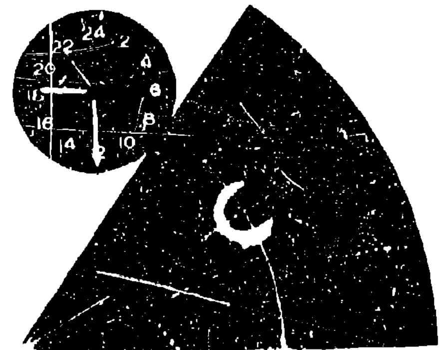


Fig. 3.1 Representative Radar Scope Photos of Shot 1. A/C Altitude 29,940 Ft; Direction From GZ 225°/27NM; Alt Delay 29,940 Ft

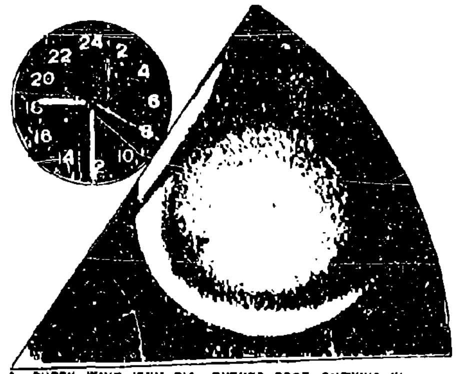


1. PHOTO AT APPROX TIME OF WEA. BURST. NOTE AREA OF NO RETURN DEVELOPING BEHIND IMPACT POINT.

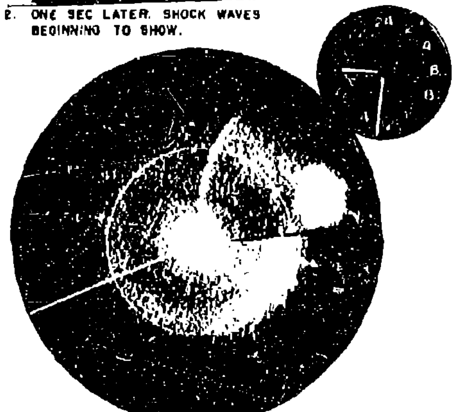


2. ONE SEC LATER. SHOCK WAVES BEGINNING TO SHOW.

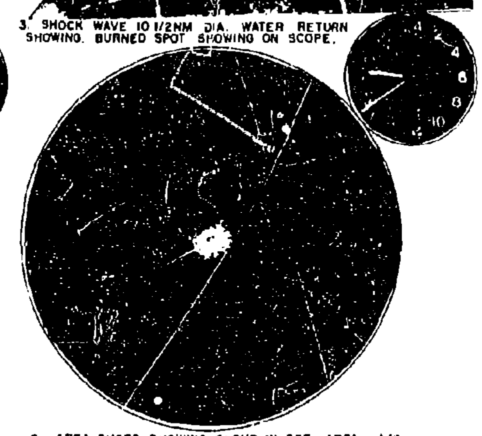
3. SHOCK WAVE 10 1/2NM DIA. WATER RETURN SHOWING. BURNED SPOT SHOWING ON SCOPE.



4. SHOCK WAVE 18NM DIA. BURNED SPOT SHOWING IN SHOCK WAVE AREA.

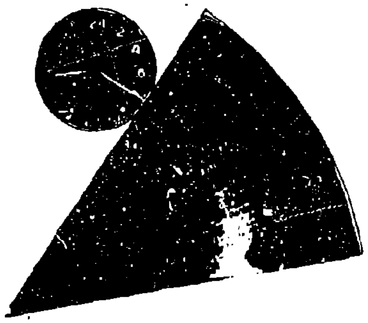


5. HIGH GAIN PHOTO. SHOCK WAVE HAS REACHED POINT ON WATER BELOW A/C POSITION. RTN. FR. BURST STILL VIS IN TGT AREA.



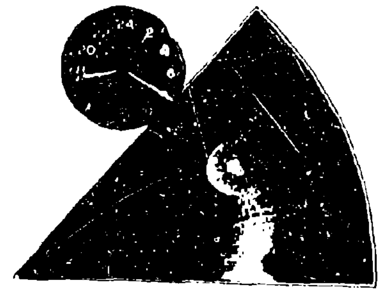
6. AREA PHOTO SHOWING CLOUD IN TGT. AREA A/C APPROX 42NM FROM TGT.

Fig. 3.2 Representative Radar Scope Photos of Shot 2. A/C Altitude 32,000 Ft; Direction From GZ 228°/15NM; Alt Delay 32,000 Ft

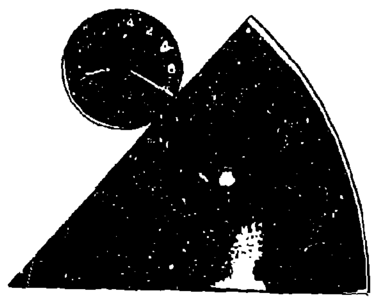


1. APPROXIMATELY AT WEAPON BURST. NOTE WEATHER ON LOWER PART OF SECTOR.

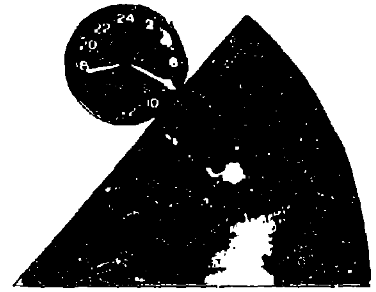
2. ONE SEC. LATER. SHOCK WAVE DEVELOPING.



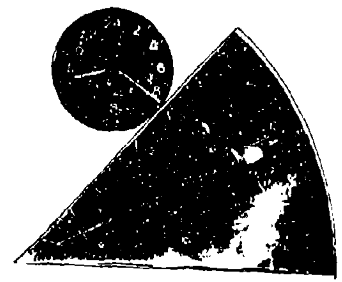
3. SHOCK WAVE APPROXIMATELY 10NM DIA. WEATHER VISIBLE LOWER PART OF SECTOR.



4. NOTE THAT SHOCK WAVE IS CLEARING WEATHER FACTORS FROM AREA AS IT MOVES OUTWARD FROM TARGET AREA.



5. SHOCK WAVE HAS APPARENTLY LITTLE EFFECT ON HEAVY WEATHER BUILD-UP AS WAVE REACHES ITS MAXIMUM DISTANCE OF TRAVEL.



6. PHOTO SHOWING RESIDUAL RETURN IN BURST AREA. WEATHER STILL VISIBLE.

Fig. 3.3 Representative Radar Scope Photos of Shot 3. A/C Altitude 32,000 Ft; Direction From GZ 230°/14NM; Alt Delay 32,000 Ft

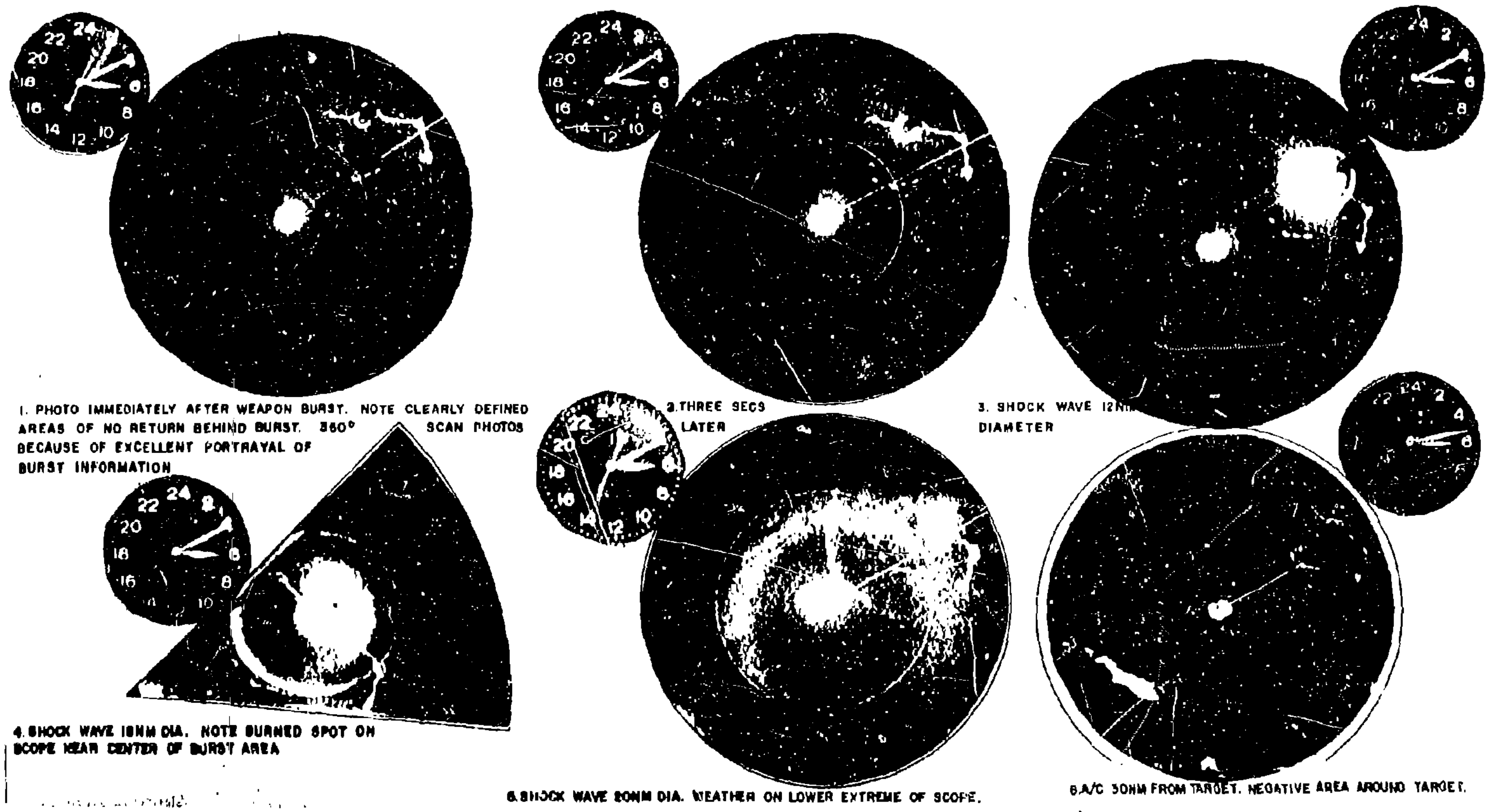


Fig. 3.4 Representative Radar Scope Photos of Shot 4. A/C Altitude 31,000 Ft; Direction From GZ 225°/22NM; Alt Delay 31,000 Ft

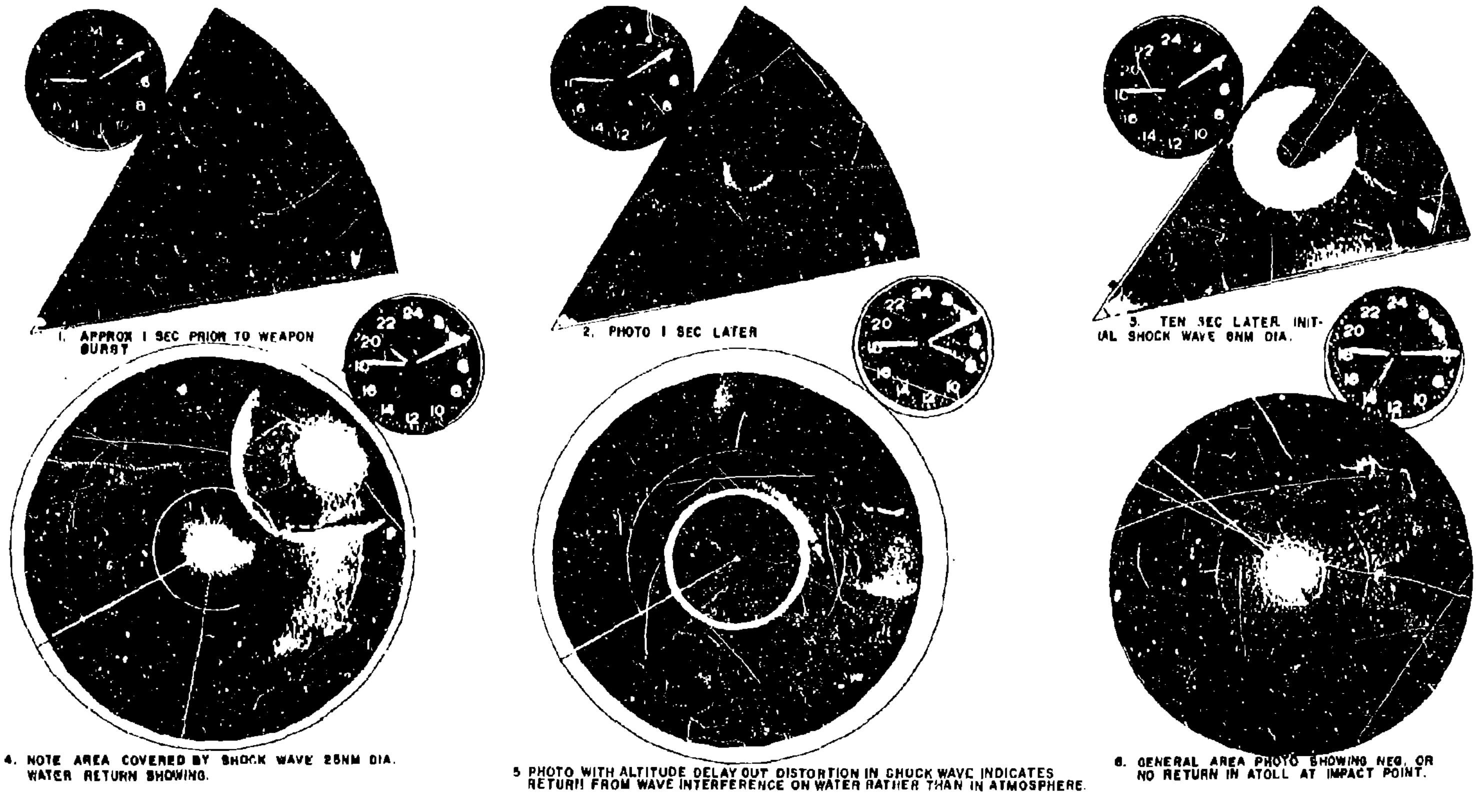


Fig. 3.5 Representative Radar Scope Photos of Shot 5. A/C Altitude 32,000 Ft; Direction From GZ 225°/18NM; Alt Delay 32,000 Ft (Except Photo Number 5 Where Altitude Delay is Zero)

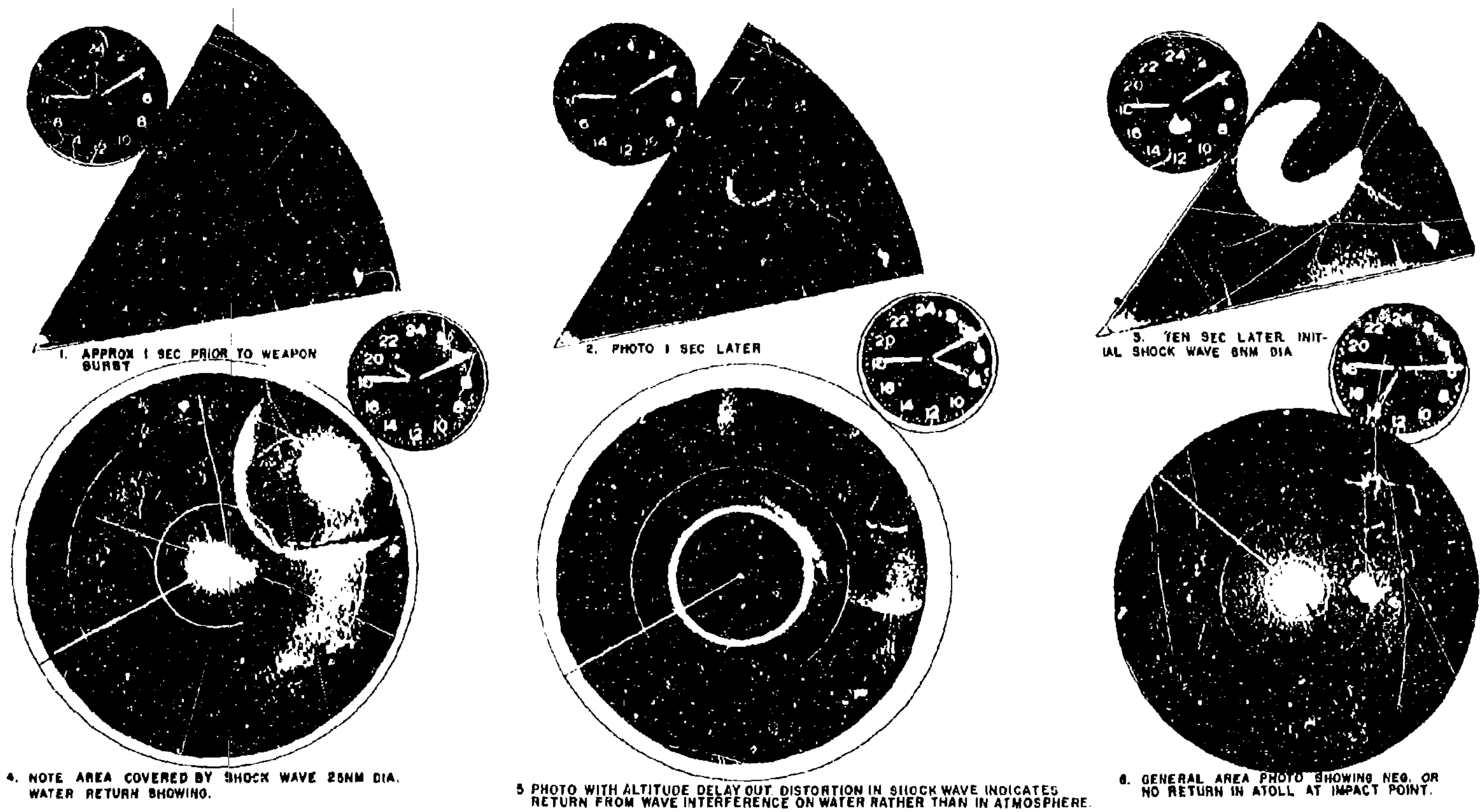


Fig. 3.5 Representative Radar Scope Photos of Shot 5. A/C Altitude 32,000 Ft; Direction From GZ 225°/18NM; Alt Delay 32,000 Ft (Except Photo Number 5 Where Altitude Delay is Zero)

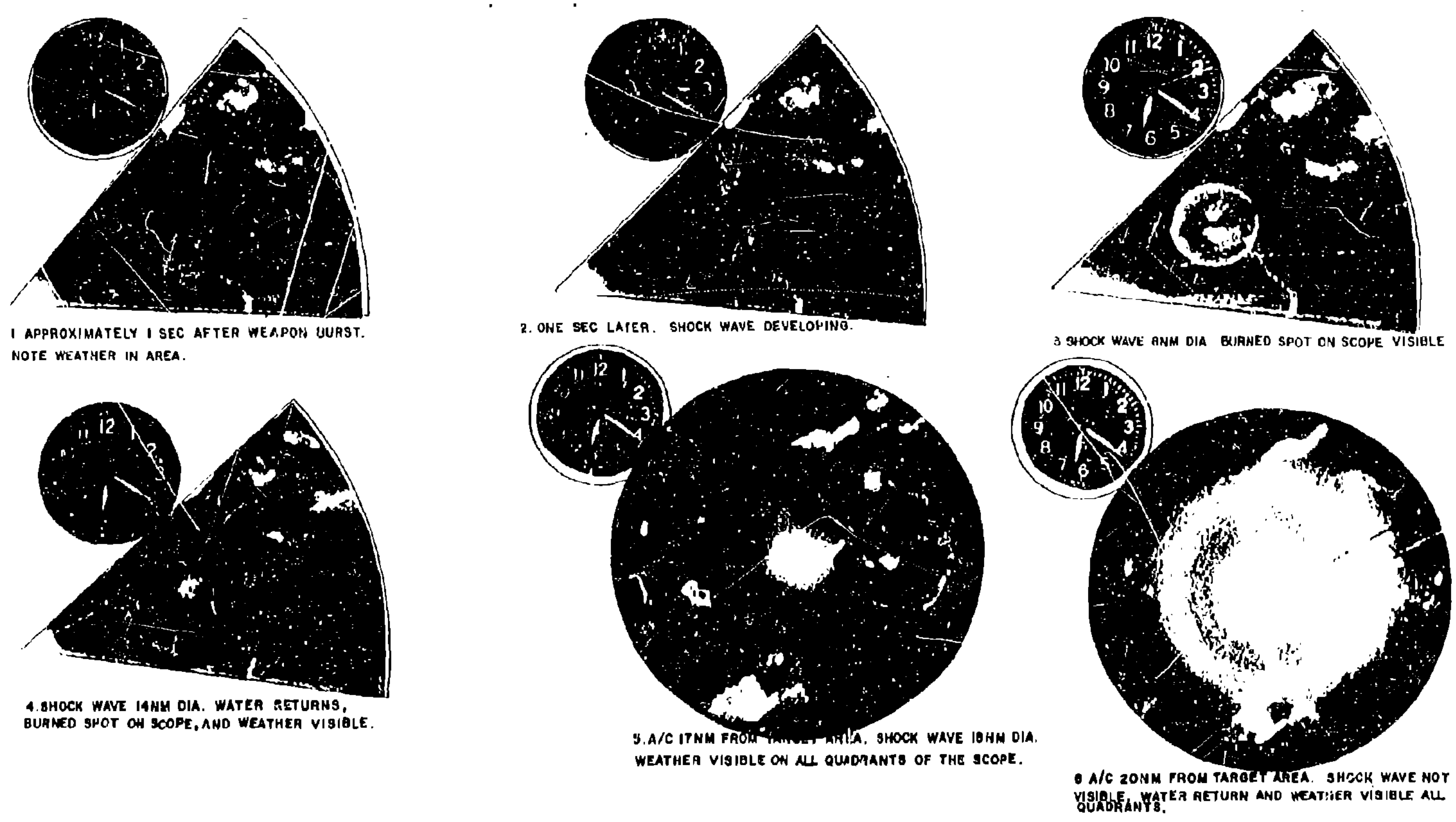


Fig. 3.6 Representative Radar Scope Photos of Shot 6. A/C Altitude 32,000 Ft; Direction From GZ 225°/15NM; Alt Delay 32,000 Ft

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Explosion of thermonuclear weapons can be detected and recorded by existing airborne navigation-bombing radars. Results of previous Atomic Energy Commission tests with atomic weapons support this conclusion.

Existing radar equipment-operating procedures are adequate for detecting and recording explosions of thermonuclear weapons. Procedures tested however, were for aircraft not actually releasing the weapon. It is believed that some minor modifications to equipment and procedures would improve the capability of a drop aircraft to record the weapons burst by radar.

The ground zero of a thermonuclear weapon explosion can be established by interpretation and plotting of radar scope photos. If instrumentation to obtain weapon yield, computations of height of burst, and target vulnerability, are all available acceptable estimates of target damage can be made. The AN/ASH-4 (Recording Set, Light and Time) will provide the weapon yield and height of burst data, and the operational commands are in possession of vulnerability data on their targets.

Recording of radar display data for IBDA can be improved through modification of existing equipment.

4.2 RECOMMENDATIONS

That further investigation of a means of instrumenting current bombing systems for determining weapon yield and height of burst by measurements on radar scope photos be abandoned and development of the AN/ASH-4 be expedited.

That efforts to improve the quantitative and qualitative recording capability of the O-15 camera be continuous with early attention given to the modifications proposed in the WADC High Information Content System study.

Future Department of Defense-Atomic Energy Commission tests of high yield weapons include IBDA projects with air releases by Strategic Air Command aircraft.

APPENDIX A

ANNEX E
TO
OPERATIONS ORDER 6-54
H-HOUR AIRCRAFT POSITION & FLIGHT PATTERN OF SAC AIRCRAFT

HEADQUARTERS
STRATEGIC AIR COMMAND
Offutt Air Force Base
14 January 1954

1. The Lead B-50D aircraft (HARDTIME 1) will fly an 8 minute race track orbit at an altitude of 34,000 ft with side of orbit nearest ground zero tangent to a circle of safe radius around the GZ (see Appendix C-1 for table of approximate safe radii). At zero time minus two minutes aircraft will initiate maneuvers so as to be tail to the shot, regardless of where aircraft is in the orbit. Orbit will have 2 minutes sides and 2 minutes turns. Aircraft will fly straight and level for 2 minutes after shot time, then resume orbiting until joined by other SAC aircraft and further instructions have been received from CIC Controller.

2. The second B-50D aircraft (HARDTIME 2) will fly an 8 minute race track orbit at an altitude of 33,000 ft with side of orbit nearest ground zero tangent to a circle of 18 miles radius around GZ. Aircraft will endeavor to be on side of orbit nearest GZ at zero time and broadside to the shot. This aircraft will fly straight and level for one minute after shot time and then establish a flight path around the GZ for 15 minutes (approximately 75 n.m. at 300 K ground-speed) maintaining as closely as possible a constant 18 n.m. distance from GZ. Pilot will maneuver aircraft as necessary to avoid bomb cloud and/or maneuver out from under bomb-cloud overhang.

3. The third B-50 aircraft (HARDTIME 3) will fly an 8 minute race track orbit at an altitude of 32,000 ft with side of orbit nearest GZ tangent to a circle of 23 n.m. radius around the GZ. Aircraft will endeavor to be on side of orbit nearest GZ at zero time and broadside to the shot. Aircraft will fly straight and level for 2 minutes after the shot,then proceed to orbit position of the Lead B-50 aircraft.

4. Task Group 7.4 may modify instructions of preceding paragraphs as regards altitudes and horizontal range from GZ for all aircraft in separate operations order for each shot.

APPENDIX B

ANNEX G
TO
OPERATIONS ORDER 6-54
RADAR OBSERVER PROCEDURES FOR
RADAR SCOPE PHOTOGRAPHY OF LARGE YIELD WEAPON BURST

HEADQUARTERS
STRATEGIC AIR COMMAND
Offutt Air Force Base
14 January 1954

1. GENERAL. The primary purpose of the SAC participation in the test is to obtain radar scope photos of the bomb burst from which photo interpreter personnel can determine location of the bomb burst with respect to other identifiable features. Previous tests have indicated that the lower the height of burst and generally, the larger the yield of the weapon, the more perceptible the burst on the radar scope. Since the yields will be considerably higher on this test than on previous tests, and because the shots will be at low burst height, it is expected that a corresponding increase in radar signal strength will be realized. However, the display of the burst on the radar scope is a fleeting one and, in order to record it, the radar procedures must at least include:

   a. Radar scanning area of the GZ.

   b. 0-15 camera taking pictures every clockwise scan.

   c. Contrast, bias, video gain, receiver gain, and antenna tilt adjusted for optimum display and even ground painting. Receiver gain should be at least high enough to display the type of positive return and resultant shadow provided by a thunderhead.

NOTE: Control settings may require varying in order to obtain best background return for plotting and yet display bomb burst. Careful critique of each mission's results should establish the optimum radar control settings and procedures for each subsequent mission.

2. PRIOR TO FLIGHT

   a. Radar maintenance personnel will use the TS-147 radar test set to measure and record the radar characteristics listed on Form Appendix G-1.

b. Radar observers will accomplish 0-15 camera pre-flight in accordance with Chapter 9, Section III, SAC Manual 50-13.

3. IN FLIGHT

a. Check 0-15 camera for operation and correct f/setting.

b. Synchronize 0-15 camera watch with hack watch.

c. Obtain radar scope photography in accordance with Change 1 (18 August 1953) to SAC Manual 50-13 (April 1952), (paragraph 5e(2) of Chapter 3, Section XI) with following exceptions and/or instructions:

(1) Since bomb will not be released from aircraft, initiate procedures specified at "bomb release" at 60 seconds prior to shot time.

(2) At bomb burst (one crew member will be designated to inform the radar observer upon visual observation of the burst), record data listed in Appendix H-1.

(3) The second B-50 aircraft (HARDTIME 2) will continue taking radar scope photography of GZ for 15 minutes, instead of the 2 minutes specified in paragraph c above. (See Annexes D and E.)

(4) Contrast setting should be set for optimum radar presentation. On previous tests a setting of "4" was used, but it is believed a setting of "2" (or less) may produce better results.

(5) A normal video gain setting should be used.

(6) Radar camera data card will be filled out in accordance with SAC Manual 50-13, except that the word "CASTLE" followed by the code word for the particular shot ("BRAVO", "UNION", etc.) will be substituted for geographical area, and the aircraft position within the SAC element (#1, #2, or #3) will be entered after the altitude.

(7) Photography obtained by HARDTIME 2 after burst (see paragraph 3c (3)) will be taken with displaced sector and showing intermittent range markers instead of switching to 360° scan as covered in paragraph 3c above. The purpose of this photography is to record, if possible, by radar a phenomena known as "base surge" which follows the bomb burst. The "base surge" is a travelling wave of suspended water, dust, etc. This photography will be used for a separate project designated "1.1C" in which SAC is assisting.

ANNEX G
TO
OPERATIONS ORDER 6-54
RADAR PHOTO DATA

HEADQUARTERS
STRATEGIC AIR COMMAND
Offutt Air Force Base
14 January 1954

Aircraft No. ____________ Type Film __________

Mission Date ____________ O-15 Camera f/Setting _______

1. Prior to Flight
   a. Transmitter power output in db __________
   b. Receiver sensitivity in db __________
   c. Transmitter frequency in mc __________
2. In-flight at Bomb Burst
   a. Time (GMT) to nearest second: __________
   b. Radar camera counter number: __________
   c. APQ-24 computer fix dials:
      (1) N-S component: _______ n.m.
      (2) E-W component: _______ n.m.
   d. Contrast setting number: __________
   e. Receiver gain setting number (see Inclosure of SAC Regulation 95-10), and remarks: ______________________________
   f. Antenna tilt setting: ____ degrees
   g. Aircraft true altitude: ____ feet
3. After Flight
   a. Transmitter power output in db __________
   b. Receiver sensitivity in db __________
   c. Transmitter frequency in mc __________

____
(Name and Rank of Observer)

APPENDIX C

ANNEX K
TO
OPERATIONS ORDER NO. 6-54
PLOTTING GROUND ZERO AND BOMB BURST HEIGHT FROM RADAR SCOPE PHOTOGRAPHY

HEADQUARTERS
STRATEGIC AIR COMMAND
Offutt Air Force Base
Omaha, Nebraska
26 February 1954

1. DESCRIPTION OF RADAR RETURNS:

   a. Atomic and thermo-nuclear weapon bursts, under favorable conditions, will produce radar returns which will allow the determinations of ground zero (GZ) and height of burst. Best data available to date indicate that the favorable conditions are as follows:

      (1) Aircraft position should be no closer than 3 n.m. ground range nor farther than 10 n.m. ground range from GZ.

      (2) The probability of obtaining a radar return increases with weapon yield. (No radar returns have been obtained to date for weapons of less than 20 KT yield.)

      (3) The probability of obtaining a radar return decreases inversely with burst height. (Best radar returns have been obtained on tower shots.)

      (4) Scope photos should show solid and even radar mapping of the GZ area (but not so saturated as to hide bomb burst return).

      (5) Rapid scanning of the GZ area.

   b. At the instant of burst, a tiny intense positive return appears at the GZ and expands rapidly in size becoming a "doughnut" shaped return or a "horseshoe" shaped return (the difference being largely due to bomb burst height). The positive return appears to be caused by the rocks, dust, and debris which are thrown up as the shock-wave of the blast travels along the surface. As rocks and the heavier debris settle to the earth behind the shock-wave, that area ceases to produce a positive

radar return, thus causing a circular positive return with a hole in the center.

(1) The intensity of the positive return decreases as the return moves outward from the GZ, and finally fades into the ground return. Because of this fact, the radar return is visible for several seconds longer over water than over land.

(2) The "doughnut" return may appear as a "horseshoe" return, with the open end on the side away from the aircraft, because the fireball and resultant cloud absorb the radar energy and cause a radar shadow to fall on the ground beyond the cloud (and also on the shock-wave effect within the shadowed area).

(3) The radar return is very fleeting, and generally appears on radar scope photography for only 4 to 10 seconds. It is so transitory that it is highly improbable that a radar observer watching his scope will detect the bomb burst returns, even though they appear on the photography.

(4) By the time the "horseshoe" had reached its maximum size, it may measure 5 n.m. or more in diameter (varying with burst height and yield).

c. The radar shadow caused by the fireball and cloud is more lasting than the positive "horseshoe" return, and has been observed for as long as 60 or 90 seconds after the bomb burst.

(1) The radar shadow when first observed is fairly small, is sharply defined when falling on solid ground mapping, and is close to the GZ. Although the fireball may be round, the angle from the aircraft will cause the shadow to appear oval (with the long axis along a radius of the scope).

(2) The radar shadow rapidly becomes more and more elliptical in shape, moves away from the GZ (on the side opposite the aircraft position), and loses its sharp outline.

(a) The movement of the shadow away from the GZ is the result of:

1 Aircraft movement.

2 Actual rising of the cloud.

3 Wind effect on the cloud.

(b) The elongation of the cloud shadow (always along a radius of the scope) is the result of:

1 The increasing horizontal separation between the cloud and the aircraft.

2 The increasing height of the top of the cloud.

3 The increasing height of the cloud above the terrain.

2. DETERMINATION OF GROUND ZERO:

a. The position of ground zero can be located on radar scope photography which displays a bomb burst return as follows:

(1) Identify the intended target area and adjacent radar returns on the radar scope photography.

(2) Identify the return produced by the bomb burst.

(3) Project the negative frame of radar scope photography bearing the bomb burst return onto a large scale chart of the GZ area (preferably 1:100,000 or 1:250,000 scale), matching radar returns with the corresponding features which produced the returns in order to establish correct scale. (A "Goldie" projector, or any other 35 mm film strip projector is satisfactory.)

(4) The center of the "doughnut" or "horseshoe" is ground zero. Therefore, where this center falls on the chart is the location of ground zero.

b. Accuracy of this determination, providing three or more adjacent radar returns can be matched with their corresponding features on the chart, is approximately ± 600 feet.

c. If the bomb burst return is visible on the photography of a strike aircraft, but no adjacent radar returns can be identified and exact aircraft position cannot be determined from surrounding radar returns or GPI readings, ground zero cannot be determined with that photography.

d. If the bomb burst return is not visible on the photography of a strike aircraft, but aircraft position at bomb release can be determined, probable ground zero can be determined with an accuracy of ± 3000 feet. (See SAC Regulation 50-30 "Photo Scored Bombing Operations" dated 24 February 1953.)

e. If the bomb burst return is not visible on the photography of a support aircraft, ground zero cannot be determined with that photography.

3. DETERMINATION OF BURST HEIGHT:

a. Bomb burst height can be estimated from radar scope photography if the bomb burst return and the cloud shadow both appear on a single photo. There is no known procedure for this computation from radar scope photos, however, if either of the phenomena is absent.

b. At the same time the ground zero is being located by projection plotting, the height of burst can be determined by the law of similar right triangles:

(1) When a ground range sweep is used by the radar (as on the normal APQ-24 or K-system bomb run), the following values are known:

a Aircraft bombing altitude (BA) — obtained from a Radar Scope Photo Log.

b Ground range to ground zero (D_1) — measured on the chart during projection plotting.

c Ground range from GZ to near edge of cloud shadow D_2) — measured on the chart during projection plotting.

(2) Height of bomb burst (HB) is the value to be found.

(3) By the rule of similar right triangles, solve for HB as follows:

$$\frac{HB}{BA} = \frac{D_2}{D_1 + D_2}$$

c. Determination of burst height from radar scope photos when the cloud shadow falls within a negative return area is not possible. The presence of lakes and radar shadows caused by uneven terrain in the GZ area seriously complicate the identification of the bomb cloud shadow.

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